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EVALUATION OF THE WESTERN SPRUCE BUDWORM

SURVEY SYSTEM IN THE LAKE STATES

FINAL REPORT

by

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INTRODUCTION

The spruce budworm (Choristoneura fumiferana (Clemens)) is a native of the Lake States (Michigan, Wisconsin, and Minnesota) where it is the major pest of balsam fir (Abies balsamea (L.) Mill.) and white spruce (Picea glauca (Moench) Voss). Budworm attacks its host in midsummer when the moths lay masses of about 25 eggs on the needles. The eggs hatch in about 10 days. The first instar larvae disperse within and between trees, then hibernate on the host. In the spring, the larvae emerge, mine a needle or two, then bore into buds. As the buds flush, the budworm larva becomes a free-feeder on expanding needles. Larvae pupate and become moths in late July.

Sampling for budworm egg masses is done in August after oviposition is complete. At this time egg mass numbers are counted to estimate expected defoliation the following year. During the same stand visit, defoliation in the current year is estimated.

There are other species of spruce budworm in western North America that feed on trees similar to balsam fir and white spruce. Because their life cycles are similar to that of spruce budworm in the East, coincidental sampling for egg masses and defoliation is used in both eastern and western surveys.

Although there is a variety of sampling systems, all involve pruning branches from the mid-crown of host trees and counting the number of egg masses found on the branch unit. Defoliation is estimated in terms of new foliage missing. An outline of the survey systems used in this evaluation is in Appendix A.

In 1977, the St. Paul Field Office cooperated with the State and Private Forestry Methods Application Group, Davis, Calif., in an evaluation of the western spruce budworm sampling system on balsam fir in the Lake States.[1] No criteria were established for the evaluation, but it was implied that the western system was useful for predicting defoliation of balsam fir from egg mass numbers counted the previous year. The evaluation began in 1977. It was also suggested that the western system would compare favorably with the eastern sampling system in precision, accuracy, and crew hours; this hypothesis was evaluated in 1979.

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[1] Hastings, A. R. Unpublished work plan on file at St. Paul Field Office, Northeastern Area, State and Private Forestry, USDA Forest Service.

A progress report on the evaluation showed that there was no significant difference between egg mass numbers counted in the field and those detected under black light in the laboratory. Twenty-seven stands (12 entomological units) were surveyed in 1977. Within stands, the standard error of the mean number of egg masses per square meter ranged from 22 to 100 percent (Hastings and Nash 1979).

This report completes the evaluation and is a summary of data gathered in 1978 and 1979.

OBJECTIVE

The objective of the pilot study was to evaluate the applicability of the western spruce budworm egg mass-defoliation sampling procedures to balsam fir stands in the Lake States.

METHOD

The western spruce budworm sampling procedures were followed in 1977, 1978, and 1979 in balsam fir stands in Michigan, Wisconsin, and Minnesota. Three national forests (Superior, Ottawa, and Hiawatha) and one state forest (Cloquet in Minnesota) were sampled. Complete egg mass-defoliation data were gathered on 11 entomological units (Ranger Districts) in 1977-1978 and on 18 entomological units in 1978-1979 (Table 1). Another four entomological units were established in 1979 for comparing 38-cm and 70-cm branch data. These units were on the LaCroix Ranger District (Superior National Forest) and on the Nicolet National Forest. The number of three-tree cluster plots within entomological units varied from one to nine (Table 1).

CALCULATIONS

The following calculations were made:

1. Mean number of egg masses/m^2 by cluster
2. Mean number of egg masses/m^2 and standard error of the mean by entomological unit (District)
3. Mean adjusted defoliation level by cluster
4. Mean adjusted defoliation level and standard error of the mean by entomological unit (District)
5. Coefficient of determination (r^2) for defoliation and egg masses/m^2 by management unit (Forest) using cluster means.
6. Selection of best fit equation to describe the relationship between egg masses/m^2 and subsequent defoliation.
7. Correlation of egg masses/branch with egg masses/m^2 for 38-cm branches using data from 37 clusters on the Ottawa National Forest.
8. Mean area of branches in m^2.
9. A Student's t test for significant difference in egg masses/m^2 between 38-cm and 70-cm branches.

RESULTS AND DISCUSSION

All egg mass population categories and defoliation classes were represented in the sample of 140 clusters examined in 1977, 1978, and 1979 (Table 2). The average number of egg masses/m^2 in a cluster ranged from 0 to 72 on 70-cm branch samples.

When cluster means were used to correlate egg masses/m^2 on 70-cm branches with subsequent defoliation for management units, r^2 values were 0.62, 0.33, and 0.23 for Superior National Forest, Ottawa National Forest, and Hiawatha National Forest, respectively. These low r^2 values indicate that the numbers of egg masses/m^2 on 70-cm branches do not correlate with the degree of defoliation the next year when sampling is done according to the western method.

The equation $Y = A + BX$ best fitted the data, where Y was the defoliation class and X was the mean number of egg masses/m^2. When the equations from the three national forests were graphed the slope (B) values were 1.7, 1.0, and 0.9. This means that on the Superior National Forest, where the budworm outbreak is only 2 years old, a small increase in the number of egg masses results in a large increase in defoliation values (slope of 1.7); whereas on the Hiawatha, which has a 5-year-old outbreak, a small increase in the number of egg masses produces only a small increase in defoliation (slope of 0.9). The Y intercept (A) in each of the national forest graphs was more than 25 because defoliation levels (Y axis) used in the western system have a midpoint value of 12.5 percent and there was considerable variation in defoliation values for any particular number of egg masses. If there had been a zero value for defoliation and if zero egg masses always resulted in zero defoliation, the Y intercept (A) would have been through the origin (zero on both axes).

The number of branch samples per tree and the number of trees per cluster were not suitable for comparing the western technique with the eastern technique for sampling spruce budworm egg masses or defoliation. To make the comparison, we would need several criteria and complete sampling. The better technique should be more accurate, more precise, and more rapidly accomplished in all phases. Some data taken according to the eastern technique could be used in a general comparison of the two techniques.

The average 70-cm branch was 57.4 cm wide and measured 0.2 m^2. The average 38-cm branch was 33.7 cm wide and measured 0.0642 m^2. This meant that three times as much area had to be searched for egg masses on the 70-cm branch as on the 38-cm branch. If the larger branches could be shown to give a better estimate of the egg mass population, the extra time needed to search them might be justified to improve precision. However, when means from 22 entomological units were compared, there was no significant difference (CL .95) in egg masses/m^2 between 70-cm branches and 38-cm branches. It seems that the 38-cm branches used in the eastern survey method took less time to search than the 70-cm branches used in the western survey system. Precision of the estimates was improved by using the 70-cm branches. In 18 of 22 entomological units, the standard error for egg masses/m^2 on 70-cm branches was less than that for 38-cm branches. The difference was about 10 percent, and ranged from -3.6 to 40 percent. The negative values were those cases, four of them, where the smaller branch gave a more precise estimate than the larger branch. Although the larger branches gave more precise estimates than the smaller branches in 82 percent of the entomological units, they did not have a standard error of less than 20 percent except in one entomological unit. The usually acceptable level of precision, and the standard used in the western system, is 20 percent of the mean.

Since the 70-cm branch requires more time to examine than the 38-cm branch, yields the same mean number of egg masses/m^2, and does not meet precision requirements, there is no need to spend time searching 70-cm branch samples. Twice as many 38-cm branches as 70-cm branches could be taken to improve precision and still reduce searching time by 15 percent, because two 38-cm branches (0.1284 m^2) have less area than one 70-cm branch (0.2 m^2).

Accuracy is at risk every time a measurement is taken. For example, computing egg masses/m^2 requires measurement of branch length and branch width and two mathematical operations. These four chances for mistakes can be reduced to one if egg masses/38-cm branch is used instead. Thirty-five cluster means from the Ottawa National Forest were used to test the correlation of egg masses/38-cm branch with egg masses/m^2 on 38-cm branches. The coefficient of determination (r^2) was 0.93 which indicates that the two measures are closely correlated. Therefore, there is no need to use egg mass numbers/m^2 when egg masses/38-cm branch yields corresponding values and requires only one measurement and one less computation.

Attempts to correlate egg mass numbers in August with defoliation levels the next August are exercises in probabilities. Between the time of egg mass sampling and defoliation sampling there are many changes in the insect population. Eggs can fail to hatch, first instar larvae disperse or die, weather and parasites destroy larvae, large larvae wander or starve, and predators eat some larvae. Tree conditions also contribute to changes in defoliation levels. A healthy tree can grow more needles than a sick tree, so a lesser proportion of new growth is eaten by a single larva. Dispersal away from a previously defoliated tree is more likely than from a healthy tree. There may be considerable feeding on old foliage (backfeeding) in heavily damaged trees. (Backfeeding is not considered in defoliation estimates.) Defoliation by other insects may be attributed to spruce budworm.

Bean and Batzer[2] recognized the changes that take place between egg mass sampling and defoliation sampling. They developed a table that shows the probability of defoliation at various levels when various numbers of egg masses are found on 15-inch (38cm) branches (Table 3A). A similar table was developed from data gathered during this evaluation of the western sampling system (Table 3B). In this case (northern Michigan and Minnesota) average number of egg masses/m^2 on six 70-cm branch tips was used as the sampling unit. These units are in classes equivalent to those in Bean and Batzer so that 3.12 egg masses/m^2 in table 3B is equivalent to 1.0 egg masses/38-cm branch in table 3A. The defoliation categories in the two tables are not equivalent. The blanks in table 3B represent data that were not present during this evaluation.

CONCLUSIONS

The western spruce budworm sampling technique is not applicable in the Lake States, according to this evaluation. Precision of the sample unit on a cluster basis was less than the acceptable 20 percent level. Counting the number of egg masses/m^2 on 70-cm branches is more time-consuming than counting egg masses on 38-cm branches, and counts do not differ significantly. Since the number of egg masses per 38-cm branch is closely correlated with the number of egg masses/m^2, the 38-cm branch is a satisfactory sampling unit.

The western sampling technique did not accurately predict defoliation of balsam fir by spruce budworm in the Lake States. The eastern sampling technique is no better in this regard; however, it is the better alternative considering sampling times, costs, and precision requirements.

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[2]/Bean, J. L. and H. O. Batzer. 1961. Unpublished Forest Service report on file at North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn.

Estimating defoliation by classifying 25 shoots, rounding the average values, then indexing to midpoints of broad classifications is too time consuming, and does not take into consideration mined buds. The Fettes system (1950), adopted by the Canada-United States Spruce Budworm Program East, includes mined buds in its classification; and the system uses more classes for increased precision.

RECOMMENDATIONS

1. It is recommended that the western spruce budworm sampling system not to be used in balsam fir stands in the Lake States.

2. It is recommended that the eastern system be tested in fir and Douglas-fir stands in the western states. Specific evaluation criteria and a complete comparison of the two systems should be made in this test.

ACKNOWLEDGMENTS

The evaluation was ′started by Art Hastings and continued by G. Lynne Whyte. Most of the statistical analysis was performed by Bob Young of the Methods Application Group, Davis, Calif. Work done by these people and the several technicians is gratefully acknowledged.

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Table 1.--Number of plots sampled for spruce budworm egg masses and subsequent defoliation by units and years

Management unit	Entomological unit	Plots sampled 1977-1978	Plots sampled 1978-1979
Superior NF	Virginia RD	1	5
	Aurora RD	7	8
	Gunflint RD	4	3
	Tofte RD	5	5
	Isabella RD	0	3
	Two Harbors RD	4	4
Total		21	28
Hiawatha NF	Rapid River RD	3	5
	Manistique RD	0	3
	Munising RD	0	5
	St. Ignace RD	0	3
	S. Ste. Marie RD	0	4
Total		3	20
Ottawa NF	Watersmeet RD	4	7
	Iron River RD	3	5
	Ontonagon RD	3	7
	Bergland RD	6	7
	Kenton RD	0	4
	Bessemer RD	0	5
Total		16	35
Cloquet SF	Cloquet	9	8
Total		9	8

Table 2.--Number of 3-tree clusters by defoliation class and spruce budworm egg mass categories, Lake States, 1977 to 1979.

Avg. No. of egg masses/m^2	Adjusted defoliation percentage[a] 12.5	37.5	62.5	87.5
0 - 0.60	31	4	0	1
0.61 - 1.56	13	2	0	0
1.57 - 3.12	6	6	3	1
3.13 - 15.58	9	17	13	5
15.59 - 31.15	0	4	8	7
31.16 +	0	1	2	7
Total	59	34	26	21

[a] Based on two branches, 70-cm long, from each tree; and 0.2 m^2/branch.

Table 3A.--Probability of different degrees of defoliation on balsam at any locality in northeastern Minnesota for the following year based on the average number of egg masses per 38-cm (15-inch) twig per collecting point

Average number of egg masses per 38-cm twig	Number of chances in 100 for the following degrees of defoliation[a]			
	None	Light	Moderate	Heavy
0 - 0.2	43	45	9	3
0.3 - 0.5	5	58	21	16
0.6 - 1.0	2	14	42	42
1.1 - 5.0		5	23	72
5.1 - 10.0			6	94
10.0 +				100

[a]Defoliation classification: light, 5 to 25 percent defoliated moderate, 30 to 50 percent defoliated; heavy, 55 percent or more defoliated.

Table 3B.--Probability of different degrees of defoliation on balsam in stands located in northern Michigan and Minnesota for the following year based on the average number of egg masses/m^2 on six 70-cm branch tips per 3-tree cluster.

Average number of egg masses/m^2	Number of chances in 100 for the following degree of defoliation[a]			
	12.5	37.5	62.5	87.5
0 - 0.60	86	11		3
0.61 - 1.56	87	13		
1.57 - 3.12	37	38	19	6
3.13 - 15.58	20	39	30	11
15.59 - 31.15		21	42	37
31.16 +		10	20	70

[a]Defoliation classification: 12.5, between 0 and 25 percent defoliated; 37.5, between 26 and 50 percent defoliated; 62.5, between 51 and 75 percent defoliated; 87.5, between 76 and 100 percent defoliated.

APPENDIX

THE METHOD USED TO

SAMPLE

WESTERN SPRUCE BUDWORM

1. Define a management unit. In this evaluation, a national forest was the management unit.

2. Within each management unit, select an entomological unit that is the smallest land unit for which data are needed. The ranger district was used for this unit.

3. Establish a cluster of three plots within each entomological unit. The first plot is selected at random, the other plots 60 meters and 120 meters from it along a straight line.

4. Select three live dominant or codominant host trees to constitute a plot.

5. From each selected host tree, prune four branch terminals (70-cm long) from cardinal directions and at mid-crown. Count spruce budworm egg masses on two of these branches and use all four for making defoliation estimates.

6. Measure the width from leaf tip to leaf tip of the two branches used for egg mass sampling and determine the foliated area in m^2 (70-cm times half the width divided by 10,000).

7. Examine the branches under black light, count the egg masses, and record the number of egg masses/m^2 for each branch.

8. Estimate defoliation of the four branches/tree by examining the first 25 current year shoots (called "buds" in western states) from the distal end of each branch. Assign to each shoot a defoliation index of 1 (0-25 percent), 2 (26-50 percent), 3 (51-75 percent) or 4 (76-100 percent). The index total for each branch is divided by 25 to arrive at an average index, and the branch averages used to calculate an average for the plot and cluster. The average index per cluster is then converted to the defoliation percentage from which 12.5 percent is subtracted to arrive at an adjusted defoliation rating. This rating is the midpoint of a range of percentage defoliation.

A METHOD USED TO

SAMPLE

SPRUCE BUDWORM IN THE EAST

1. Select management units, entomological units, clusters, plots and sample trees as for the western spruce budworm sampling system. Usually, however, a plot consists of five trees.

2. The number of clusters is dependent upon sample variance; but for moderate to high populations of egg masses, 12 to 15 clusters are used in an entomological unit of about 4,000 ha.

3. Prune three branch tips (38-cm long) from the mid-crown of each sample tree to use for egg mass sampling, and an additional two branches to make a total of five branches to be used for defoliation estimates.

4. Examine all new shoots and mined buds on each branch, and assign a rating to each according to the 10 percent increment codes developed by Fettes (1950). An average rating is then calculated for each cluster.